GALACTIC AND EXTRAGALACTIC STUDIES, II. NOTES ON THE PECULIAR STELLAR SYSTEMS IN SCULPTOR AND FORNAX

BY HARLOW SHAPLEY

HARVARD COLLEGE OBSERVATORY

Communicated October 7, 1939

1. *Results of a General Search.*—The examination of one hundred and fifty-two small-scale plates, covering something more than fifteen thousand square degrees of the sky in galactic latitudes higher than $\pm 20°$, has failed to show any other objects similar to the stellar systems in Sculptor and Fornax reported last year.[1] The plates were made at the Boyden Station, Bloemfontein, with the AX camera attached to the Bruce telescope; the exposures are each uniformly three hours in length; the scale is 1 mm = 11'.5. Since the new objects in Sculptor and Fornax are readily shown on such plates, we must infer from the fruitless search that stellar systems of this sort are infrequent in the neighborhood of our Galaxy and probably not frequent within a million light years.[2]

In the course of the search, two new globular clusters and two new objects of the Magellanic Cloud type have been noted. The new globular clusters are in (or superposed upon) the Fornax system. One, of magnitude 14.2, is in the position $2^h\ 35^m\ 58^s$, $-34°58'$ (1900), practically at the center of the system.[3] The other, a loose globular cluster near the southern edge, is in the position $2^h\ 34^m\ 33^s$, $-35°14'$, and of magnitude approximately 14.4. There is a third very faint cluster of unidentified character, magnitude 16.6:, at $2^h\ 35^m\ 56'$, $-34°51'$, which is also probably a part of the Fornax system.

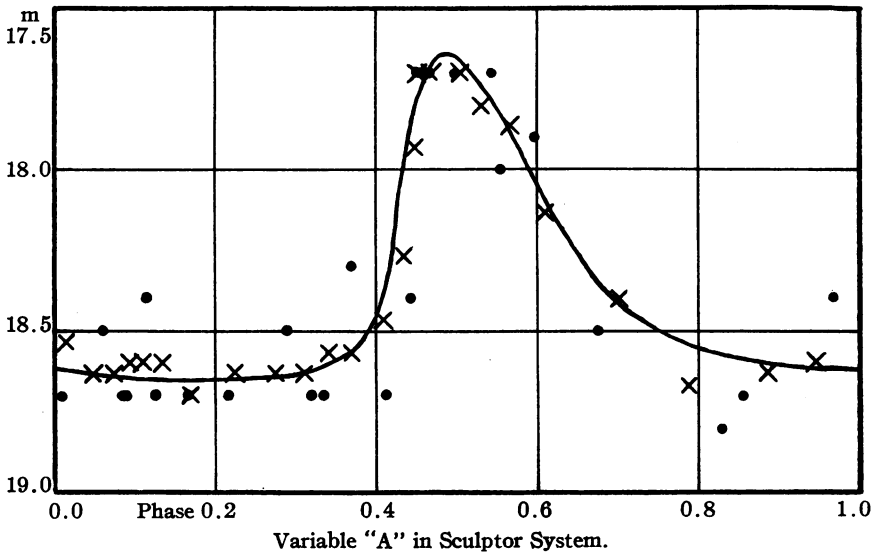
2. *Description of the Two Objects.*—Because of the probable significance of the Sculptor and Fornax systems in the sequence of galactic forms, a further report is now made, with special reference to the distances of the two objects and to the brightness and distribution of stars throughout the one in Fornax.

An important addition to our knowledge of the new systems has resulted from the preliminary investigations by Baade and Hubble with the aid of photographs made with the 100-inch reflector at Mount Wilson.[4] Chiefly through the discovery of faint variable stars in the Sculptor system, the Mount Wilson observers show that the preferred hypothesis as to distance, dimensions and luminosity is almost certainly correct; that is, the systems are of the size of the average galaxy, but have low total intrinsic brightness and are devoid of supergiant stars. They are members of the local group of galaxies.

The positions, apparent magnitudes and angular dimensions of the two objects are as follows:

	SCULPTOR CLUSTER	FORNAX CLUSTER
Right ascension (1900)	$0^h\ 55^m.4$	$2^h\ 35^m.6$
Declination (1900)	$-34°\ 14'$	$-34°\ 53'$
Galactic latitude	$-83°$	$-64°$
Galactic longitude	243°	203°
Total photographic magnitude	9.0:	9.0:
Magnitude of brightest stars	17.8	19.3
Mean angular diameter	75′	65′

3. *Classical Cepheids in the Sculptor System.*—Plates made with the 24-inch and 60-inch telescopes in South Africa permit the derivation of provisional periods and light curves for the two bright variable stars in the Sculptor cluster, which were found on Mount Wilson plates. As suspected, the stars apparently are classical Cepheids. Provisionally, periods of about 6.518 days and 1.35 days, for Variables A and B, respectively, have been determined by Miss Swope from the few observations now available, but for the second star other values are not excluded.



Variable "A" in Sculptor System.

In the accompanying figure the dots indicate single observations on Variable A; the crosses are running means. The magnitude scale is necessarily precarious for such faint objects in declination −34°. With no correction for space absorption the median photographic magnitudes of the two variables are 18.2 and 18.1; and the mean absolute magnitude, with half weight for Variable B, is −1.2.

4. *Distances and Absolute Magnitudes.*—The high galactic latitude, $\beta = -83°$, and the faintness of the classical Cepheids in the Sculptor cluster make it extremely improbable that the variables are merely superposed members of the Galaxy. Accepting that they are members of the system, we find, in the mean, 76 kiloparsecs for the distance of the Sculptor system, in agreement with my originally suggested value of 80 kiloparsecs, based on the magnitudes of the brighter stars, and with the value of 84 kiloparsecs estimated by Baade and Hubble from the magnitudes at maxima of the numerous faint (presumably cluster-type) variables that they observed. There are, however, serious uncertainties involved and the probable error of the deduced distance may easily exceed ten per cent.

The Sculptor and Fornax systems, though 21° apart, appear together on some of the small-scale plates now available at Harvard and the total apparent magnitudes can therefore be compared directly. Revising somewhat an earlier estimate, we now find that the Fornax system is at least as bright as the Sculptor cluster; both are uncertainly placed at apparent magnitude 9.0. The absolute magnitudes, on the other hand, appear to differ considerably. The plates made with the Boyden Station 60-inch reflector show, as also do the Mount Wilson plates, that the most luminous individual stars in the Fornax system are about a magnitude and a half fainter than those in the Sculptor cluster. We infer, therefore, that either the relative frequencies of the absolute magnitudes of their stars are quite different, or the Fornax cluster is twice as far away as the Sculptor cluster and intrinsically brighter. Baade and Hubble suggest, on the basis of the magnitudes of the brighter stars in the presumably associated globular cluster NGC 1049, that the Fornax cluster is 2.2 times as distant as the system in Sculptor.

With the distances as indicated above, the total absolute magnitudes of the Sculptor and Fornax systems, -10.5: and -12:, are of the same order as the absolute magnitudes of the brightest globular clusters and the small unresolved spheroidal galaxies, such as the companions of the Andromeda Nebula (M 32 and NGC 205). Similar also in absolute magnitude, Baade and Hubble point out, is IC 1613, a dwarf irregular galaxy (Magellanic type) which is being extensively studied by Baade.

The similarity in total luminosity and probably in total mass of three such systems as Omega Centauri, NGC 205, and the Sculptor cluster, should be of significance in the interpretation of large stellar systems, notwithstanding the differences of these organizations in structure. All three are centrally, but not highly, concentrated and appear to be oblately spheroidal (NGC 205 particularly oblate). All are devoid of supergiant stars. NGC 205 is intermediate in dimensions, the Sculptor cluster in luminosity.

It is interesting to note that a view of our galaxy from the region of the

Andromeda Nebula would show it to be accompanied by several "small spheroidal galaxies"—that is, by the brightest of the globular clusters. Omega Centauri, 47 Tucanae, and similar giant globular clusters should probably be given galactic rank if the companions to the Andromeda Nebula are placed in that category. The Sculptor and Fornax systems might be called greatly expanded giant clusters; but speculation on their nature and relationship to other galactic structures could better await improved information about the luminosity functions involved and the total magnitudes.

5. *Star Counts in the Fornax System.*—A survey of the distribution of several thousand of the brightest stars in the Sculptor cluster has been given in an earlier paper.[5] The individual stars in the Fornax cluster are too faint for satisfactory counting on the Bruce long-exposure photographs, since the brightest individual stars are fainter than magnitude 19. An attempt to count the stars and study the distribution on reflector plates gives only provisional results because the small curved field of the reflector is unsuited to the study of such an extended object. On a plate showing stars on the optical axis to magnitude 20.5, approximately, 4800 stars have been counted in an area of thirty-five per cent of a square degree, and in a central area of eight per cent of a square degree, where the distance correction is unimportant, 2300 stars, of which approximately six per cent are members of the foreground. On the basis of these counts, and the distribution of stars on a series of surrounding long-exposure reflector plates, we conclude that the structure of the Fornax cluster is much the same as that of the nearer system in Sculptor.

6. *Angular and Linear Dimensions.*—The star counts fail to give the full extent of the Fornax system, but a measure of its dimensions has been derived from twenty tracings, made with the photoelectric densitometer, on two three-hour plates of the AX series. The means of the measures in four position angles by Shapley and Miss Patterson are as follows:

	Core	±	Envelope	±
E–W,	38′	2′.1,	71′	1′.9
NE–SW	44	2.6	63	1.5
N–S	41	2.7	71	1.5
NW–SE	34	2.0	52	3.1

The tabulated mean errors indicate only the uncertainty of the measurements. A three-hour Bruce plate shows a hundred faint background galaxies in the area covered by the Fornax system, the richness being practically the same as in the surrounding area and showing the general transparency of the system.

It is difficult in measuring such a faint object to determine with accuracy where the cluster fades into the galactic star field. But the diameter of the Fornax system is certainly not less than 40′, corresponding

to about two kiloparsecs, and more probably it is at least fifty per cent larger. The mean angular diameter of the Sculptor system, derived from the star counts on two Bruce plates,[5] is 75′, corresponding to a linear diameter of 1.8 kiloparsecs. These linear dimensions are comparable with those of average spheroidal galaxies and with that of the main body of the Small Magellanic Cloud.

From the tabulated measures it is seen that the inner part of the Fornax cluster is distinctly elongated, NE to SW, although the faint outermost envelope is more nearly circular. The phenomenon of a corona of stars, spheroidal in shape whatever the basic form of the underlying structure, is thus indicated in projection for both of these new objects and is beginning to appear as a significant structural feature common in stellar systems. Already it has been shown that an "escape atmosphere" surrounds the Andromeda Nebula. The galactic system apparently is similarly constructed, as illustrated by the observations reported in the preceding paper of this series. Around the two Magellanic Clouds are also such extensions—envelopes in which are found scattered giant stars, star clusters and classical Cepheid variables.

[1] The objects were described in detail at the Cambridge meeting of the British Association for the Advancement of Science, August, 1938; see also *Harv. Bull.* **908** (1938) and *Nature*, **143**, 715 (1938).

[2] Examination of the AX plates has been carried through chiefly by Miss Martha Dowse and Miss Rebecca Jones, who have had extensive experience in the study of faint galaxies.

[3] This object is also noted by Baade and Hubble; they give 15.0 as a preliminary estimate of the apparent magnitude; *Pub. Astr. Soc. Pac.*, **51** (February, 1939).

[4] Loc. cit., *supra*.

[5] *Harv. Bull.* **908** (1938).

THREE SUPERNOVAE IN THE SPIRAL NGC 3184

BY HARLOW SHAPLEY

HARVARD COLLEGE OBSERVATORY

Communicated October 13, 1939

In the recent discovery in the northern spiral NGC 3184 of three highly luminous variable stars, all probably of the supernova class, the observatories at Palomar, Mount Wilson and Harvard have collaborated. The three stars appeared within an interval of sixteen years, two of them indeed were at maximum in 1921—an indication that in some external systems there may be a particularly high frequency of supernovae. (The general infrequence of such outbursts has been established by Zwicky at Palomar, and verified at least qualitatively by Harvard observers.) Similarly in both NGC 4321 and NGC 6946 two supernovae have appeared, separated by in-